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BLOOD GAS ANALYSERS: A BUYER'S GUIDE

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In January 2006 the UK National Health Service (NHS) Purchasing and Supply Agency (PASA) Centre for Evidence based Purchasing (CEP) published a survey of 14 blood gas analysers (see "Further reading"). This article is based on information contained in that report.

What they are and what they can measure

Blood gas analysers have been a feature of point-of-care testing (POCT) for many years. The range of analysers available on today's market (see table 1) is varied and encompasses a wide range of measurements, including electrolytes, metabolites and CO-oximetry plus an extensive selection of calculated parameters. The choice of an analyser will depend on the specific requirements of the unit it is to serve and careful consideration of the utility of the features on offer. Workload is a key consideration and a guide to the suitability of different systems is included in this article.

How they work

The measurement system generally consists of a selection of small electrodes, which are in contact with a sample held in a measurement chamber. The signals from the patient sample are compared with those from liquid or gaseous calibrants, to provide pH and partial pressures of oxygen and carbon dioxide. Analysers that also provide electrolyte and metabolite measurement use specific electrodes; measurement of haematocrit is by conductivity. CO-oximetry uses spectrophotometry to measure haemoglobin derivatives and oxygen saturation.

The sensors used in most blood gas analysers are based on similar principles to each other, using potentiometric or amperometric measurements, but there are notable exceptions. The OPTI CCA uses fluorescence sensors called optodes, and the recently released NPT7 uses dry optical technologies, utilising spectrophotometry, infrared spectroscopy and phosphorescence quenching.

The analysers have individual containers for calibrants, wash solution and waste collection. These can be combined in various ways: *e.g.* grouped reagent containers, or a single pack containing not just the reagents but also the sensors and a waste compartment. Where sensors are not included in the reagent pack, they may be supplied as a cassette or singly. Single sensors may be disposable or require maintenance.

There are several different forms in which reagents and sensors may be provided. Single- or multi-use cartridges containing sensors, reagents and waste compartment are disposed of when all specified measurements have been made. Some analysers have multi-use reagent packs and separate sensors provided either individually or as a cassette. Others use some multi-reagent or individual reagent containers. Individual sensors in different analysers may be disposable or require maintenance.

Issues for consideration in making a choice

Parameters.

- The number of possible measured analytes can range from 3–19. Various analyte selections are offered by different models or cartridges in the same analyser series. It should therefore be possible to match your requirements quite closely.
- Additional parameters are calculated or estimated using measured and keyed-in data and some preset defaults. Again the available range is wide (10–49) and varies between analysers, so check the specifications carefully. Most analysers provide a core group, including total carbon dioxide concentration, base excess (both blood and extracellular fluid), bicarbonate and temperature-corrected values for pH, carbon dioxide and oxygen pressure. Almost all analysers provide oxygen saturation and haemoglobin, but these can be either measured or calculated.
- CO-oximetry measurements are provided on most of the larger blood gas analysers. The NPT 7 is the only smaller analyser which offers just blood gases and CO-oximetry.

Sample.

- All systems analyse whole blood, but two of those on the market can also measure gases in expired air samples; two others offer serum or plasma measurement of some analytes.
- All analysers accept samples from syringes or capillary tubes and some manufacturers provide their own. The requirements for anticoagulation may vary between analysers and must be followed. Correct sample handling before measurement is vital if reliable results are to be obtained. ▶

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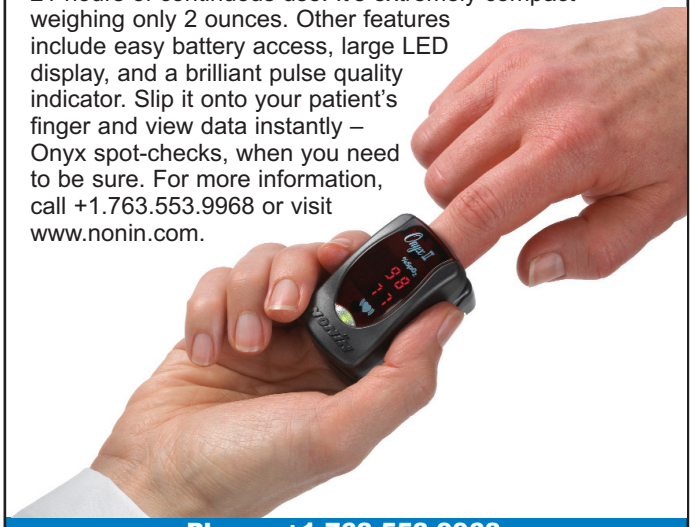

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- The majority of blood gas analysers now require quite small sample volumes, but some provide the option of fewer tests when the sample is very small. This may be of particular importance in neonatal units.
- Sample entry is by aspiration for the majority of analysers. This reduces the risk of contaminating the analyser with blood, as can occur when samples are injected.

Consumables.

- The use of liquid-only reagents is now common and the absence of gas cylinders simplifies maintenance.
- The amount of electrode maintenance required varies between analysers. Consider the potential for staff cost-savings when choosing systems whose electrodes require no maintenance.
- For the most economic use, it is important to match multi-use cartridge size and on-board life to sample throughput.
- A display of the number of samples that can be measured before a cartridge must be changed is the easiest way to monitor reagent consumption. The majority of non-cartridge-based systems use percentage of reagent volume remaining, which is not so informative.
- Refrigerated storage of consumables may be a significant issue in POCT.

Quality control.

- Freshly tonometered blood measured as a patient sample is the ideal quality control (QC) system, but this is impracticable, so measuring aqueous materials sealed in single-use ampoules is the norm. Automatic measurement of QC solutions is the most convenient method, but only the analyser is tested, not operator technique. Intelligent Quality Management cartridges for the GEM Premier 3000 analyser provide much faster error detection than conventional auto-QC. Again, the potentially higher costs of auto-QC should be balanced against savings made in operator time.
- Reusable electronic checking devices are provided for regular QC of single-use cartridge systems, with liquid QC material only being required for checking new batches of cartridges.
- There are important QC software features that should be available. Levey–Jennings plots clearly identify drifting of in-range QC results over time, which could indicate an analyser problem. QC lockout has the advantage of automatically preventing measurement of any analyte

Manufacturer	Bayer Healthcare LLC				
Device	**Rapidlab 1200**	**Rapidlab 800**	**Rapidlab 348**	**Rapidlab 248**	**Rapidpoint 400**
Analytes measured (see key)	Blood gases Electrolytes Metabolites Oximetry	Blood gases Electrolytes Metabolites Oximetry	Blood gases Electrolytes, Hct	Blood gases	Blood gases Electrolytes, Hct Glucose Oximetry
Calculated parameters	up to 26	up to 29	up to 20	up to 15	up to 30
Sample types & volumes	35–175 µL whole blood	35–175 µL whole blood 10 mL expired air	30–95 µL whole blood	30–85 µL whole blood	100 µL whole blood
Workload suitability*	High	High	Low	Low	High
Consumables presentation	Multi-use cartridge + wash, waste cartridge	Individual reagent containers + external gas cylinders	Individual reagent containers + internal gas cartridges	Individual reagent containers + external gas cylinders	Multi-use cartridges + wash, waste cartridge
Maintenance	Medium	High	Medium	Medium	Low
Operator interface	Touch screen, bar code reader	Keypad, bar code reader	Keypad	Keypad	Touch screen, bar code reader
Dimensions HxWxD (mm)	578 x 520 x 533 29.5 kg	508 x 559 x 483 29 kg	371 x 386 x 380 9.1 kg	371 x 386 x 321 9.1 kg	555 x 300 x 420 15.5 kg

Key: **Blood gases**: pO_2, pCO_2, pH; **Electrolytes**: Na, K, Ca, Cl; **Hct**: haematocrit determined using conductivity; **Metabolites**: glucose, lactate; **Oximetry**: tHb, sO_2, FO_2Hb, *F*COHb, *F*MetHb, *F*HHb

***All systems may be considered suitable for medium workload (10-20 samples/day). This classification indicates whether they are additionally most suited to either a higher or lower sample throughput and does not mean they are totally unsuitable for other workload levels.**

whose last QC result was unacceptable.

- Participation in an external quality-assessment scheme (EQAS) provides a more rigorous check of individual analyser performance than internal quality-control measurements. Participation is essential at all POCT sites. Peer-group QC monitoring schemes such as those run by Radiometer and Nova are not a replacement for EQAS involvement since they are based on internal QC measurements alone.

Reliability.

- Automatic suppression of unreliable results is important, especially for POCT. This could arise because the results are outside the measurement range of the analyser, or follow a failed QC measurement.
- Correct pre-analytical handling of the sample is vital for obtaining reliable results.
- Manufacturer's performance data for the 14 analysers fully evaluated in CEP report 05091are available at www.pasa.nhs.uk/cep. User comments on reliability are included in the full report.

Analyser/operator interface.

- Provision of password-only access to the analyser is especially important in POCT, to ensure ▶

Manufacturer	Radiometer Medical ApS			Abbott Laboratories Ltd
Device	ABL800	NPT7	ABL77	I-Stat 1 IA
Analytes measured (see key)	Blood gases Electrolytes Metabolites Oximetry Neonatal: *F*HbF + bilirubin	Blood gases Oximetry	Blood gases Electrolytes, Hct	Blood gases Electrolytes, Hct Metabolites: + urea creatinine
Calculated parameters	up to 49	up to 17	up to 22	up to 10
Sample types & volumes	35–195 µL whole blood	90 µL whole blood	70 µL whole blood	16–95 µL whole blood
Workload suitability*	High	Low	Low	Low
Consumables presentation	Individual reagent containers + disposable gas cylinders	Single-use cuvettes stored in disposable cartridges	Multi-use calibration pack + disposable sensor cassette	Single-use disposable cartridges
Maintenance	High	Low	Low	Low
Operator interface	Touch screen, bar code reader	Touch screen, bar code reader	Touch screen, bar code reader	Keypad, bar code reader
Dimensions HxWxD (mm)	550 x700 x 530 32 kg	220 x 340 x 420 11 kg, semi-portable	330 x 200 x 230 7.2 kg, portable	235 x 72 x 77 0.635 kg, portable

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that only fully trained staff can use the analyser. The best password source is individual barcodes, *e.g.* on staff ID badges.

- Patient, operator and sample request information entered by touch-screen or barcode scanner is rapid and potentially easier than using a keyboard.
- A facility to ensure the compulsory entry of patient identification is an advantage, permitting use of any patient-recognition analyser function and result storage in electronic patient records.
- Electronic result storage capacity on the analyser and the availability of connectivity systems are particularly important where sample throughput is high and where transfer of results to electronic patient records is required.

Maintenance.

- Requirements vary greatly between analysers and are often linked to sample throughput. An estimated relative rating of maintenance is given in the large table. Single- or multi-use cartridges containing all reagents, sensors and a waste compartment have the lowest maintenance.
- Maintenance complexity and the time required to carry it out will

Manufacturer	Instrumentation Laboratory	International Technidyne Corporation	Medica Corporation	Nova Biomedical Corporation	
Device	GEM Premier 3000/OPL	IRMA	EasyStat	CCX	pHOX
Analytes measured (see key)	Blood gases Electrolytes: (Not Cl), Hct Metabolites	Blood gases Electrolytes, Hct Metabolites: + BUN/urea, creat (Not lactate)	Blood gases Electrolytes: (Not Cl), Hct	Blood gases Electroytes: + Mg, Hct Metabol: + urea, creat Oximetry	Blood gases Electrolytes, Hct Metabolites
Calculated parameters	up to 21	up to 10	up to 14	up to 26	up to 21
Sample types & volumes	135–150 µL whole blood	125–200 µL whole blood	95–120 µL whole blood	60–210 µL whole blood, plasma or serum	40–125 µL whole blood
Workload suitability*	Low and high	Low	Low	High	Low
Consumables presentation	Multi-use cartridges	Single-use disposable cartridges	Multi-use calibrant cartridges	Multi-use calibrator packs	Single multi-use calibrator pack
Maintenance	Low	Low	Medium	High	High
Operator interface	Touch screen, bar code reader	Touch screen, bar code reader	Keypad, bar code reader	Touch screen, keyboard, bar code reader	Keypad, bar code reader
Dimensions HxWxD (mm)	432 x 305 x307 13.4 kg, semi-portable	127 x 292 x 241 2.4 kg, portable	320 x 370 x 180 7.7 kg, portable	437 x 567 x 348 24.1 kg, semi-portable	381 x 305 x 381 8.2 kg, semi-portabl

Key: **Blood gases**: pO_2, pCO_2, pH; **Electrolytes**: Na, K, Ca, Cl; **Hct**: haematocrit determined using conductivity; **Metabolites**: glucose, lactate; **Oximetry**: tHb, sO_2, FO_2Hb, *F*COHb, *F*MetHb, *F*HHb

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influence running costs for an analyser. Gas cylinder and sensor maintenance will generally require technical support. POCT staff usually take on only basic maintenance tasks. Some connectivity systems enable certain maintenance tasks to be performed from a central location, allowing the most efficient use of technical staff.

- Automatic prompts for maintenance tasks are useful.
- Automatic programmable cleaning and calibration cycles aid the continued reliable performance of the analyser.

Safety.

- Waste-collection into a sealed system is the safest option. If the system is not sealed, a warning and/or automatic analyser stop when the waste bottle is full reduces the risk of overflow.
- Presentation of the sample to an extended probe for aspiration is a potential injury risk to the operator, but is avoided on those analysers where the probe extends into the syringe after it has been seated in a sample port.
- Ease of cleaning and decontamination of the sample entry area and exterior of the analyser is an important consideration. ▶

Manufacturer	Osmetech Inc		Roche Diagnostics
Device	OPTI CCA	Opti CCA Touch	cobas b 221 (OMNI S)
Analytes measured (see key)	Blood gases Electrolytes Glucose Oximetry: tHb, sO_2 only	Blood gases Electrolytes Glucose Oximetry: tHb, sO_2 only	Blood gases Electrolytes, Hct Metabol: + urea Oximetry: not *F*HHb Neonatal: *F*HbF + bilirubin
Calculated parameters	up to 19	up to 19	up to 39
Sample types & volumes	125 µL whole blood	125 µL whole blood	40–200 µL whole blood, plasma or serum
Workload suitability*	Low	Low	High
Consumables presentation	Single-use disposable cassettes + internal gas bottle	Single-use disposable cassettes + internal gas bottle	Two multi-reagent packs, separate wash & waste bottles
Maintenance	Low	Low	High
Operator interface	Keypad, bar code reader	Touch screen, bar code reader	Touch screen, bar code reader
Dimensions HxWxD (mm)	124 x 362 x 230 4 kg, portable	124 x 362 x 230 5.5 kg, portable	590 x 510 x 600 45 kg

Key: **Blood gases**: pO_2, pCO_2, pH; **Electrolytes**: Na, K, Ca, Cl; **Hct**: haematocrit determined using conductivity; **Metabolites**: glucose, lactate; **Oximetry**: tHb, sO_2, FO_2Hb, *F*COHb, *F*MetHb, *F*HHb

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- Analyser status and troubleshooting
- Readiness for use should be clearly indicated, preferably with a distinctive arrangement of coloured lights or text.
- Automatic detection of short samples, air bubbles and clots is better than reliance on visual inspection. A few analysers provide automatic systems to remove clots from the sample pathway.
- Technical backup will be required for solving significant analyser problems, but is less likely to be needed when using single- or multi-use cartridges.

Instructions for use.

- Short-form instructions are important for POCT and ideally should include pre-analytical sample handling, sample and QC measurements, an outline of maintenance requirements and any necessary software information. If they are not provided by the manufacturer, they should be produced locally. Lamination increases durability and allows the instructions to be kept clean.
- Many manufacturers now provide operator and reference manuals in electronic format. This makes searching for information much easier and has space-saving advantages over paper manuals, but it does require access to a PC, which may not be available close to the analyser.

Training.

- Effective training of all staff who use the analyser is very important. Many manufacturers offer different levels of training for different staff *e.g.* POCT users and technical backup staff. All offer training at the customer's site, but a few manufacturers offer residential training courses for the more advanced technical training.
- It is important that pre-analytical sample handling is included in training.
- Consider the full cost implications of in-house cascade training *versus* refresher training provided by the supplier.
- On-board videos on analyser use can be helpful for training by hospital staff.
- Each trainee should complete a competency assessment before being issued with a password permitting access to the analyser. Continued possession of a valid password should depend on successful completion of refresher training and further competency assessments.

Customer support.

- Ensure that the supplier will install the analyser and provide initial training.
- Check the options for maintenance contracts, and make sure that their response times and repair facilities are adequate for your needs. Are engineers available at night or weekends? Single-use cartridge systems have agreements whereby faulty analysers are replaced by loaned analysers during repair, but check the loan replacement turnaround time.
- The ideal telephone helpline should be available 24 hours a day, every day, to reflect the use patterns of many POCT blood gas analysers.

Costs.

- It is impossible to provide actual costs, since they are subject to so many influences, *e.g.* the number of analysers, the length of the contract or whether the manufacturer is trying to establish a new product on the market.
- Suppliers can offer various financial packages *e.g.* capital purchase, lease purchase or a cost-per-test option. If the last is considered, potential future increases in sample throughput should be taken into account.
- It is important to look out for hidden costs, such as a connectivity system that costs extra for each analyser.
- The higher cost of an analyser or additional features could be offset by other savings due to its ease of use. Less maintenance may be required, training may take less time and the operator may require less technical skill.

In all situations, sample throughput has a very important influence on the choice of the most appropriate analyser. Once you have a clear idea of all your requirements, your choice of analysers will be dictated by your priorities. ■

Blood gas analysers	Manufacturers
i-STAT 1 IA	Abbott Point of Care (Division of Abbott Laboratories) 104 Windsor Center Drive, East Windsor, NJ 08520, USA. www.abbottpointofcare.com
Rapidlab 1200 FLEX series Rapidlab 800 series Rapidlab 348 Rapidlab 248 Rapidpoint 400 series	Bayer Healthcare LLC (Subsidiary of Bayer Corporation) East Walpole, MA 01032-1597, USA. www.bayer.com
GEM Premier 3000	Instrumentation Laboratory 113 Hartwell Avenue, Lexington, MA, USA. www.ilww.com
IRMA	International Technidyne Corporation 8 Olsen Avenue, Edison, NJ 08820, USA. www.itcmed.com
EasyStat	Medica Corporation 5 Oak Park Drive, Bedford, MA 01730, USA. www.medicacorp.com
CCX pHOX	Nova Biomedical Corporation 200 Prospect Street, Waltham, MA 024574-9141, USA. www.novabiomedical.com
OPTI CCA OPTI CCA Touch	Osmetech Inc., Critical Care Division 235 Hembree Park Drive, Roswell, GA 30076, USA. www.osmetech.com
ABL800 FLEX NPT7 ABL77	Radiometer Medical ApS Akandevej 21, DK-2700 Brønshøj, Denmark. www.radiometer.com
OMNI S	Roche Diagnostics GmbH. Kratkystraße 2, A-8020 Graz, Austria. www.roche.com

Table 1. Manufacturer information.

FURTHER READING

1. Pearson S, Bennitt W, Halloran SP, Thomas A, Vandyken S. Report 05091. Survey of fourteen blood gas analysers. London, NHS Purchasing and Supply Agency, Centre for Evidence-based Purchasing, 2006. Available at www.pasa.doh.gov.uk/evaluation/docs/pathology/Report_05091.pdf. Accessed: July 13, 2006.
2. Guildford Medical Devices Evaluation Centre website. http://www.surrey.ac.uk/GMEC/Pages/GuildfordEvaluations/PreviousReports/Reports/BloodGas/BloodGas.html. See Analyte availability on the blood gas analysers and Manufacturers' responses for individual analysers. Accessed: July 13, 2006.